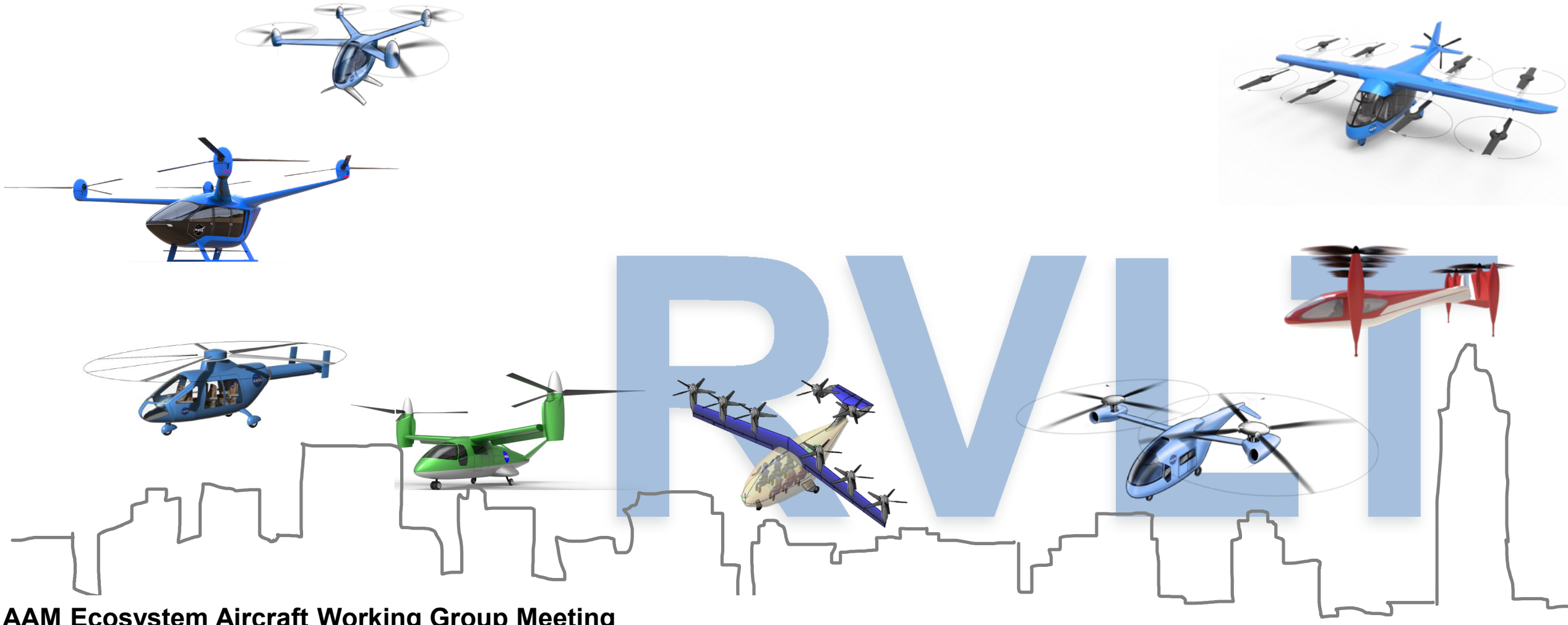
Revolutionary Vertical Lift Technology (RVLT) Overview



AAM Ecosystem Aircraft Working Group Meeting
Electric Propulsion for Urban Air Mobility

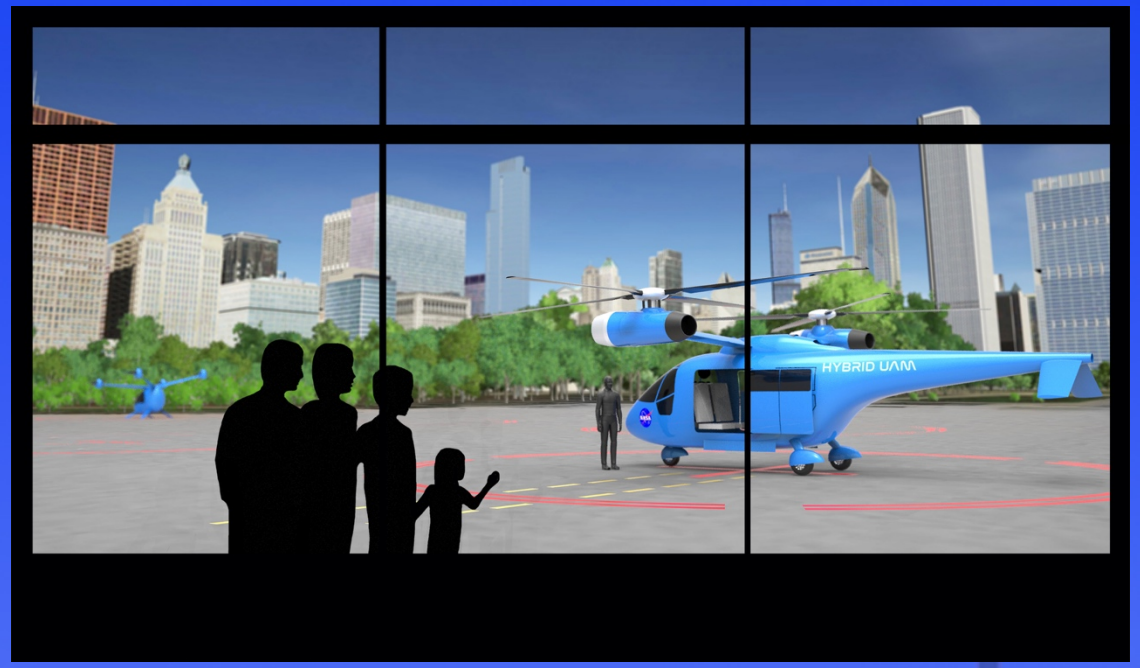
Peggy Cornell
NASA GRC, eVTOL Propulsion Subproject

Sept 30, 2021

Summary

NASA RVLT is focused on

- Vertical lift supporting Urban Air Mobility
- Three On-going Tech Challenges
  - Electric propulsion reliability and performance
  - Tools to compute vehicle source noise and performance
  - Fleet noise
- Approving new Tech Challenges
  - Ride quality and passenger acceptance
  - Crash safety



Our vision is to create a future where VTOL configurations operate quietly, safely, efficiently, affordably and routinely as an integral part of everyday life.

AAM and UAM

NASA Focus is on Advanced Air Mobility (AAM) Missions

- AAM missions characterized by < 300 nm range
- Vehicles require increased automation and are likely electric or hybrid-electric
- Rural and urban operations and cargo delivery are included
- Urban Air Mobility (UAM) is a subset of AAM and is the segment that is projected to have the most economic benefit and be the most difficult to develop
  - UAM requires an advanced urban-capable vehicle
  - UAM requires an airspace system to handle high-density operations

https://www.nasa.gov/aam-studies-reports/

NASA Concept Vehicles – Generic Geometries that Capture Many UAM Features

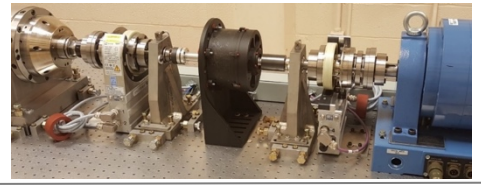
NASA reference vehicles ◆ Widely shared ◆ Fully documented ◆ Realistic performance ◆ Realistic set of compromises ◆ No plans to build or fly these concepts ◆

- Vehicles contain relevant UAM features and technologies
  - Battery, hybrid, diesel propulsion
  - Distributed electric propulsion
  - High efficiency rotors
  - Quieter rotors
  - Wake interactions
- Provide configurations for
  - Communication of NASA's Urban Air Mobility research
  - Design and analysis tool development
  - Technology trade studies and sizing excursions
  - Modeling operational scenarios
  - Common configurations for studies in acoustics, flight dynamics, propulsion reliability, etc.

RVLT Near Term Focus for Research

FY21-FY23

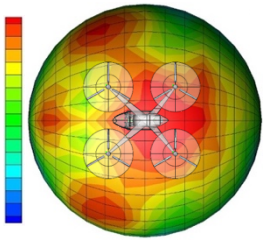
Vehicle Propulsion Reliability



Tech Challenge: Reliable and Efficient Propulsion Components for UAM

- Re-configure laboratories for electric propulsion testing
- Conduct initial single string tests
- Develop tools to assess motor reliability
- Develop high reliability conceptual motor design

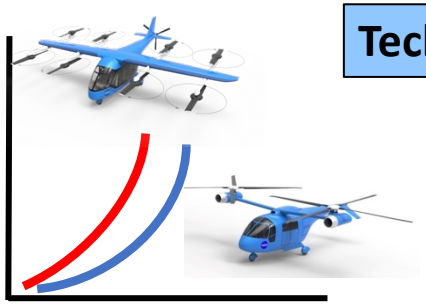
UAM Fleet Noise



Tech Challenge: UAM Operational Fleet Noise Assessment

- Generate Noise Power Distance (NPD) database for several UAM reference configurations and trajectories
- Conduct fleet noise assessments
- Initiate psychoacoustic testing to assess human response to UAM vehicles

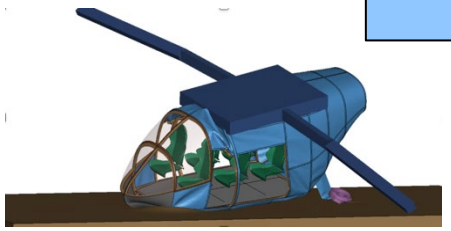
Noise and Performance



Tech Challenge: Tools to Explore the Noise and Performance of Multi-Rotor UAM Vehicles

- Plan and conduct validation experiments
- Improve efficiency and accuracy of conceptual design tools
- Conduct high-fidelity configuration CFD for validation and reference
- Improve community transition and training for analysis tools

Safety and Acceptability



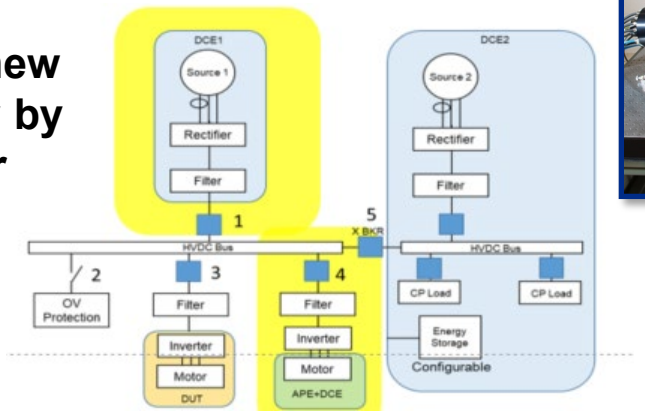
Targeted Research in These Areas for Future Tech Challenges

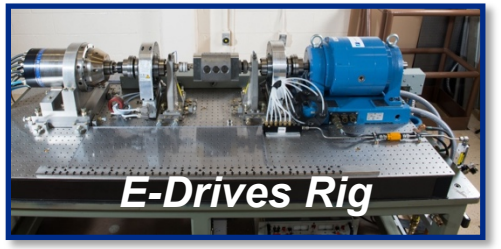
- UAM crashworthiness and occupant protection
- Acceptable handling and ride qualities for UAM vehicles
- Ice accretion and shedding for UAM

RVLT.TC.UAM.Electric.1
Reliable and Efficient Propulsion Components for UAM

Objective

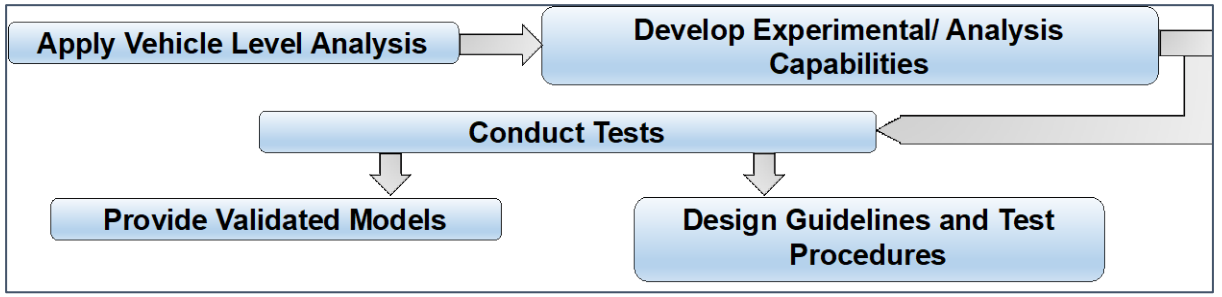
- **Develop design and test guidelines, acquire data, and explore new concepts that improve propulsion system component reliability by several orders of magnitude over state-of the-art technology for UAM electric and hybrid-electric VTOL vehicles.**





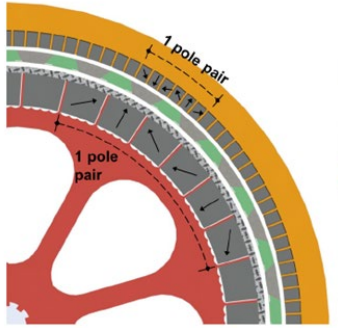
Approach

- **Iterative design, model, test and analyze**
  - Apply vehicle level analysis
  - Develop experimental / analysis capabilities
  - Conduct tests (reliability of components, tool validation)
  - Provide validated models
  - Develop design guidelines & test procedures



Benefit/Pay-off

- **Validated power/propulsion/thermal models**
- **High reliability motor design – feasibility of 2-4 orders of magnitude reliability improvement**
- **Design guidelines for eVTOL propulsion and thermal components**
- **Test guidelines for propulsion and thermal components**
- **Candidate HVDC Power Quality and Permanent Magnet Machine Standards**

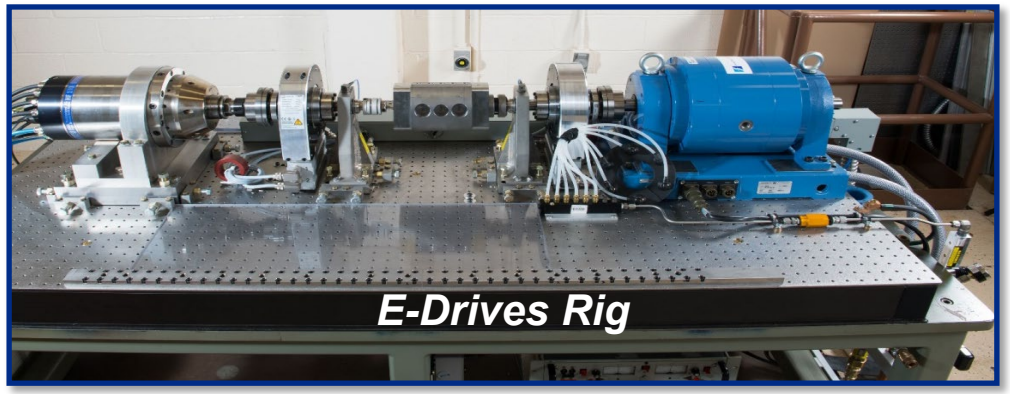


eVTOL Power / Powertrain Testbeds

- **Scaled Power Electrified Drivetrain (SPEED) -Low-Power Testbed**
  - Low power (up to 9 kW) motor & controls
  - Low voltage test platform for high power testbed hardware

- **Advanced Reconfigurable Electrical Aircraft Lab (AREAL) - High Power Testbed**
  - Emulated, reconfigurable system (single-string, multi-string)
  - 1kVDC Peak, nominal 200kW source

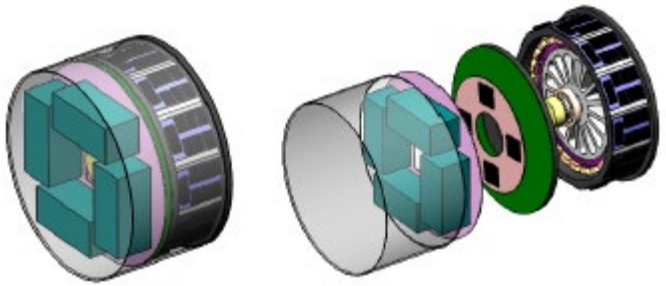
- **E-Drives Rig**
  - Test motors, gearboxes & power electronics
  - Emulation of rotor loads
  - Mechanical, electrical, vibration, & thermal measurements

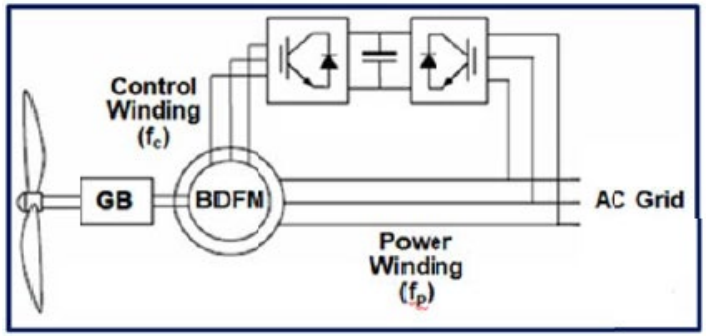


RVLT Motor Design Efforts – Goal: Improved Motor Reliability

- **External Efforts[1]: 2 Contract Funded Design**

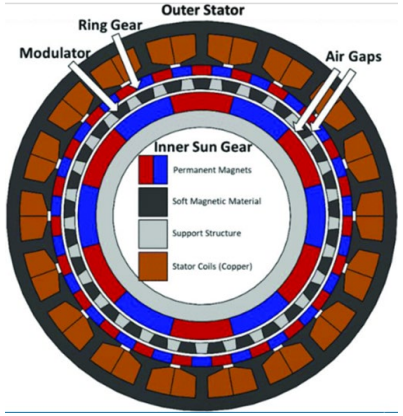
1) University of Wisconsin via OSU ULI
   - Integrated, fault-tolerant motor/drive design for RVLT quadcopter
2) Balcones Technologies vis Phase III NASA STTR
   - Developing Brushless Doubly-Fed Machine (BFDM) design for RVLT-class vehicle (100-200 kW)

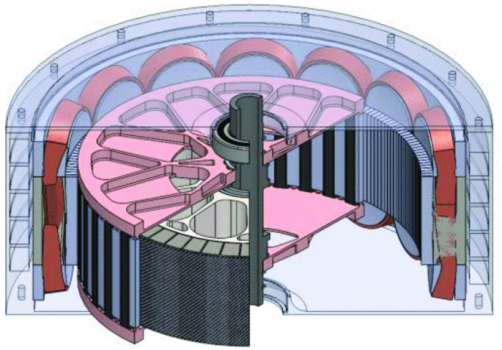




- **Internal Efforts[2]:**

1) Magnetically Geared Motors and Novel Designs
   - Exploring trade space of reliable motor topologies for UAM applications using in-house codes.
     Example: Outer Stator Magnetically Geared Motor
2) Winding Reliability Model Development
   - Developing modeling and experimental capability to explore/predict winding reliability





1. J. Swanke, T. Jahns, “Reliability Analysis of a Fault-Tolerant Integrated Modular Motor Drive (IMMD) for an Urban Air Mobility (UAM) Aircraft Using Markov Chains.” 2021 AIAA/IEEE Electric Aircraft Technologies Symposium (EATS).
2. T. F. Tallerico, Z. A. Cameron, J. J. Scheidler and H. Hasseeb, "Outer Stator Magnetically-Geared Motors for Electrified Urban Air Mobility Vehicles," 2020 AIAA/IEEE Electric Aircraft Technologies Symposium (EATS), New Orleans, LA, USA, 2020, pp. 1-25.

Standards & Tools

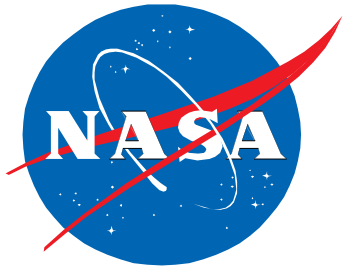
- **Leading two SAE standards**
  - AS7499 - *Aircraft High Voltage Power Quality Standard (D. Sadey)*
  - AS8441 – *Minimum Performance Standard for Permanent Magnet Propulsion Motors and Associated Drives (Pat Hanlon)*
- **Participate in AAM (UAM) Aircraft Design & Development Working Group**

AAM Working Groups (internal to government)

To collaborate and coordinate research findings across the NASA research portfolio with the relevant FAA Lines of Business to efficiently address gaps in technology, policy, and regulations to operationalize AAM in a timeframe consistent with Congressional and FAA guidelines through:

- **Prioritizing needs and gaps**
- **Centralizing AAM collaboration and coordination**
- **Jointly developing use cases, concepts, requirements, and research findings**
- **Transitioning and implementing appropriate research findings**

- **Developing Analysis Tools:**
  - **NPSS**
    - **Developed high level electrical power system models & electrical port for architecture trades**
    - **Demonstrated electrified propulsion system models**
    - **Accepted into next release of NPSS**
  - **EPS-SAT**
    - **Electrical power system sizing**
    - **Utilized for trade studies and sensitivity analyses**
  - **Toolset for Motor Reliability**
    - **Reliability Modeling of Electric Motor**


NASA